Project Report

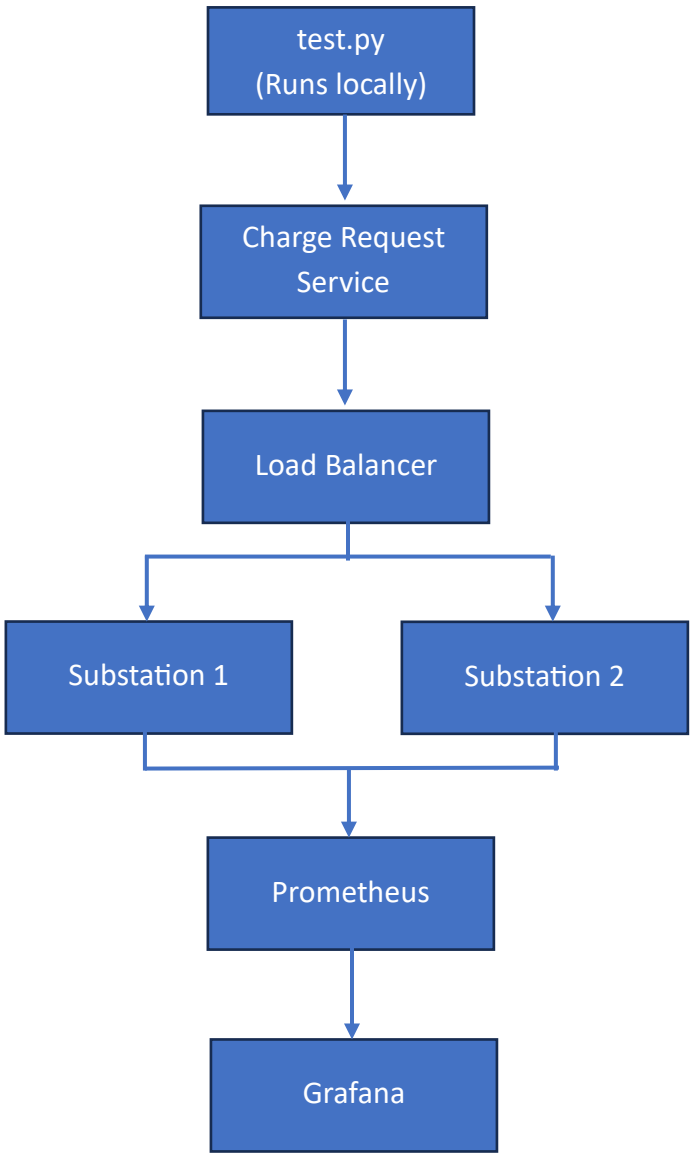
Part 2

Dynamic Load Balancing for a Smart Grid

Github Link: https://github.com/Kush220997/smart-grid-load-balancer

In this assignment the objective is to design and build a scalable system for a Smart Grid that dynamically balances Electric Vehicle (EV) charging requests across multiple substations based on their real-time load.

The assignment follows the below overall architecture:



Below are the descriptions of each file that are used to implement the dynamic load balancing of EVs charge requests:

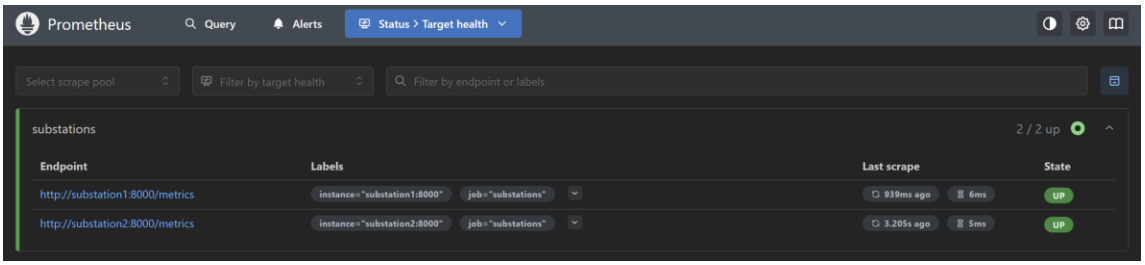
Folder	File	Logic(Process)
charge_request_service	main.py	Accepts charge requests and forwards them to load balancer
	Dockerfile	For containerizing main.py
load_balancer	main.py	Performs check on load of substations and routes the requests to least loaded substation
	Dockerfile	For containerizing main.py
substation_service	main.py	Tracks how many Evs are charging and simulates the substation
	Dockerfile	For containerizing main.py
load_tester	test.py	It sends multiple charging requests to charge_request_service
smart-grid-load-balancer	docker-compose.yml	This is the main orchestration file that defines all services & helps in network communication between services
monitoring/prometheus	prometheus.yml	This is a monitoring tool that captures the logs of Evs charging
monitoring/grafana	dashboard.json	Queries the metrics from prometheus

Below are the steps followed to complete the assignment:

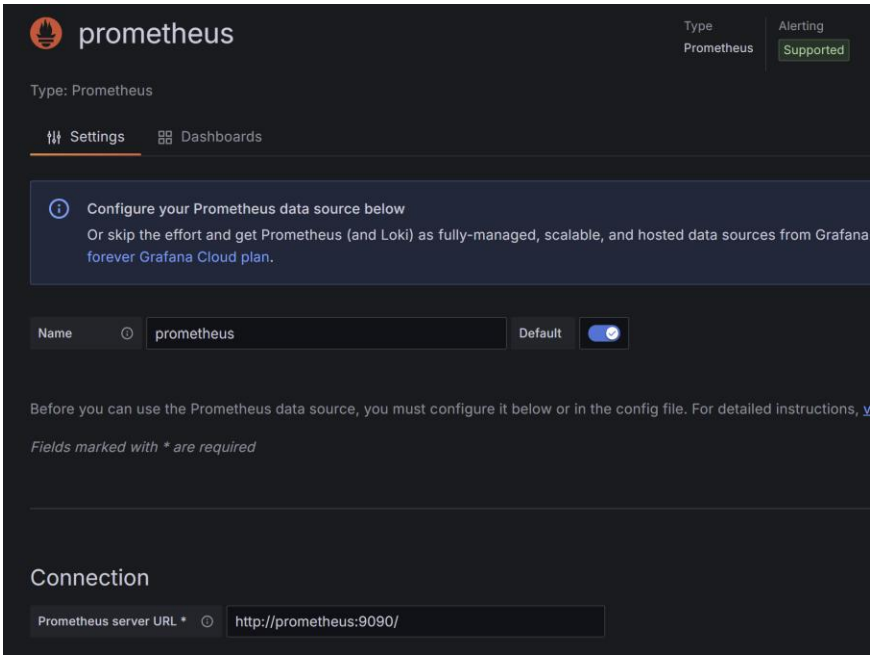
- After preparing all the files I ran the command “docker-compose up --build” which created and started all the services defined in the docker-compose.yml file.

```
[+] Running 11/11
 ✓ charge_request                                    Built
 ✓ load_balancer                                     Built
 ✓ substation1                                       Built
 ✓ substation2                                       Built
 ✓ Network smart-grid-load-balancer_default          Created
 ✓ Container smart-grid-load-balancer-substation1-1  Created
 ✓ Container smart-grid-load-balancer-prometheus-1   Created
 ✓ Container smart-grid-load-balancer-substation2-1  Created
 ✓ Container smart-grid-load-balancer-grafana-1      Created
 ✓ Container smart-grid-load-balancer-load_balancer-1  Created
 ✓ Container smart-grid-load-balancer-charge_request-1  Created
```

- Then I checked if Prometheus is up and running using http://localhost:9090/targets



- Then using http://localhost:3000 I opened Grafana dashboard and linked Prometheus to it using URL: http://prometheus:9090/ under “add connections”.



- Then I imported the dashboard.json into Grafana.

- Then I ran the python file “test.py” which sent multiple EVs charging requests to charge_request_service which forwarded the requests to load_balancer that gets the load of each substation from substation_service and allocates the charging request to least loaded substation.

```
PS C:\Users\Kush\Downloads\smart-grid-load-balancer\load_tester> python test.py
Request 1: {'result': 'Charging started'}
Request 2: {'result': 'Charging started'}
Request 3: {'result': 'Charging started'}
Request 4: {'result': 'Charging started'}
Request 5: {'result': 'Charging started'}
Request 6: {'result': 'Charging started'}
Request 7: {'result': 'Charging started'}
Request 8: {'result': 'Charging started'}
Request 9: {'result': 'Charging started'}
Request 10: {'result': 'Charging started'}
Request 11: {'result': 'Charging started'}
Request 12: {'result': 'Charging started'}
Request 13: {'result': 'Charging started'}
Request 14: {'result': 'Charging started'}
Request 15: {'result': 'Charging started'}
Request 16: {'result': 'Charging started'}
```

```
substation1-1     | 172.18.0.6 - - [25/Jun/2025 05:50:40] "POST /begin_charging HTTP/1.1" 200 -
load_balancer-1   | 172.18.0.7 - - [25/Jun/2025 05:50:40] "POST /assign_substation HTTP/1.1" 200 -
charge_request-1  | 172.18.0.1 - - [25/Jun/2025 05:50:40] "POST /initiate_energy_transfer HTTP/1.1" 200 -
substation2-1     | 172.18.0.6 - - [25/Jun/2025 05:50:40] "POST /begin_charging HTTP/1.1" 200 -
load_balancer-1   | 172.18.0.7 - - [25/Jun/2025 05:50:40] "POST /assign_substation HTTP/1.1" 200 -
charge_request-1  | 172.18.0.1 - - [25/Jun/2025 05:50:40] "POST /initiate_energy_transfer HTTP/1.1" 200 -
charge_request-1  | 172.18.0.1 - - [25/Jun/2025 05:50:41] "POST /initiate_energy_transfer HTTP/1.1" 200 -
load_balancer-1   | 172.18.0.7 - - [25/Jun/2025 05:50:41] "POST /assign_substation HTTP/1.1" 200 -
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substation1-1     | 172.18.0.6 - - [25/Jun/2025 05:50:42] "POST /begin_charging HTTP/1.1" 200 -
load_balancer-1   | 172.18.0.7 - - [25/Jun/2025 05:50:42] "POST /assign_substation HTTP/1.1" 200 -
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```
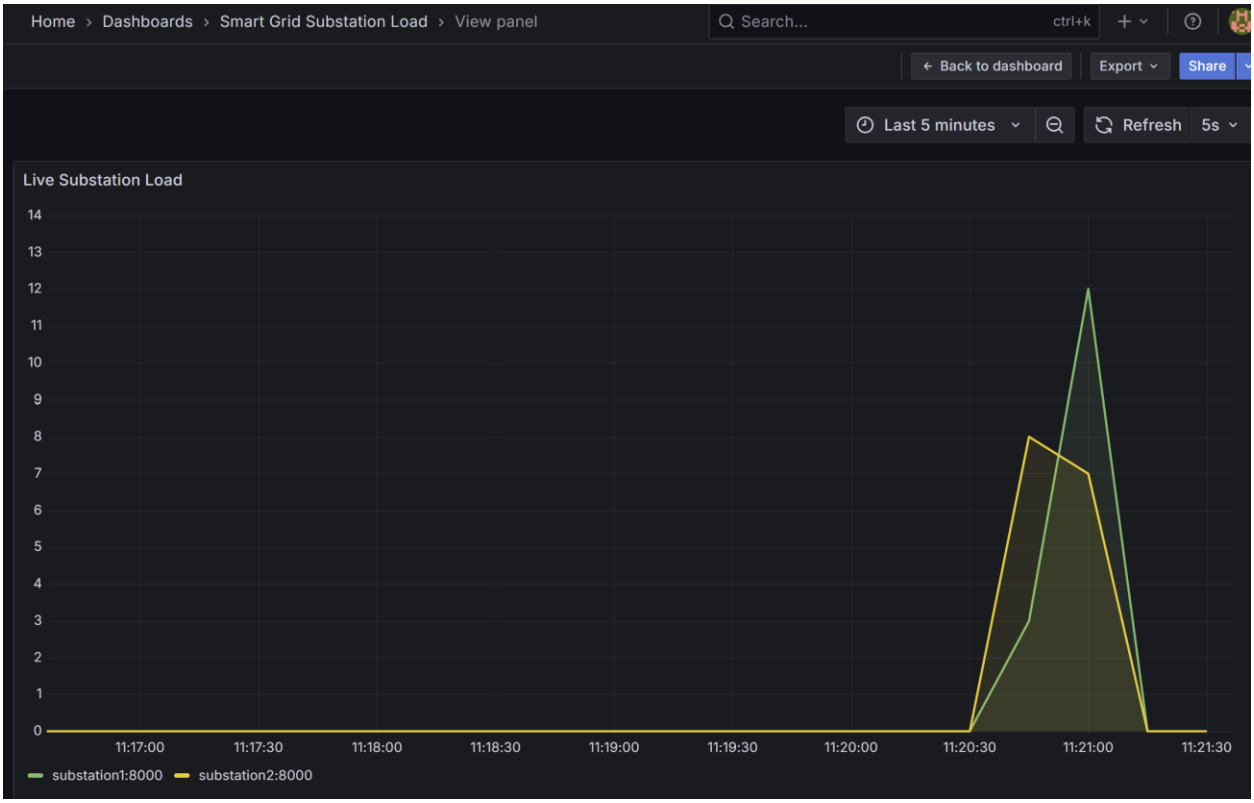

- After running test.py I am able to see the spikes in Grafana dashboard as below:



Video Link:

https://drive.google.com/file/d/1LJoLgcZEQwzN6ifElZrbBPqwsBes9dLJ/view?usp=sharing

Conclusion:

As seen in the working of the dynamic load balancing of a smart grid, the system effectively distributes EV charging requests to the least-loaded substations. The system is also integrated with Prometheus & Grafana which helps in continuous monitoring of load in each substation's.

By,

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